# 3D Balanced SSFP Imaging of Arterial Arrival Time and Perfusion in Abdominal Organs Using Arterial Spin Labeling

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**INTRODUCTION:** Arterial Spin Labelling (ASL) is a well-established method for imaging and measuring perfusion in the brain (1). However, perfusion imaging may have many important applications outside of the brain. Many cancerous lesions are highly vascular and as a result may show increased blood flow. ASL techniques may, therefore, be of potential importance for the detection and monitoring of suspicious lesions. Recent work has shown the potential of the technique, imaging specific lesions in the kidney in 2-D (2). However, for a full assessment of known and new lesions a fully three-dimensional imaging modality is needed. In addition to abnormal perfusion, pathologic changes may lead to changes in the arrival-time, the period of time taken for blood to reach the tissue from some arbitrary point upstream in the vessel. Delayed arrival times in the perfusion of the brain are well-known in stroke patients and those with carotid artery stenoses (3, 4). Dynamic contrast-enhanced imaging studies can yield arrival time information; however, the temporal resolution is limited by the passage of the bolus of contrast agent. ASL methods utilise arterial water as an endogenous tracer, and therefore, are not limited to a single pass and may offer fine temporal information.

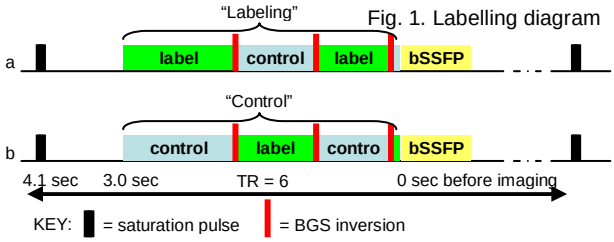


Fig. 1. Labelling diagram

**METHODS:** 3-D perfusion images were obtained in a healthy volunteer combining a pulsed-continuous ASL (pCASL) sequence (5) with a balanced Steady State Free Precession (bSSFP) signal-acquisition (6), used for its favourable sensitivity. The pCASL labelling plane was located axially at the level of the diaphragm. Labelling was continuously applied for 3 sec up to the imaging time. Spatially selective background suppression (BGS) pulses were applied during the labelling period in order to minimise subtraction-error artefacts in the perfusion image. Periods between BGS pulses were alternated between pCASL 'label' and 'control'; the sequence inverted to give a control condition (Figure 1). A half-alpha pulse and 5 dummy-scans were used to initialise the steady-state of the bSSFP sequence. Centric-ordered interleaves in the slice-encode direction and partial-Fourier, linear, centre-out encoding in the phase-encode direction was used to maximise the sensitivity of the steady-state sequence to the prepared magnetisation. Cardiac triggering was employed to minimise variation in labelling and imaging due to cardiac pulsatility. A large, 40-cm field of view covered the entire abdomen, with an image matrix of 256x128 or 128x128. The number of slice encodes was varied from 56 to 8 to give fine 5-mm slice resolution and thick 40-mm sections. Scan times were, respectively, ~10 min and 96 sec. Subjects maintained an end-expiration position for imaging, breathing between imaging and labelling modules. Vessel suppression was used in some experiments. A series of RF pulses, similar to RF spoiling with an additional applied gradient, were played between labelling and signal acquisition to saturate moving spins in the vasculature. Dynamic perfusion images were obtained by commencing labelling later, allowing less time before imaging for labelled blood to reach the tissue.

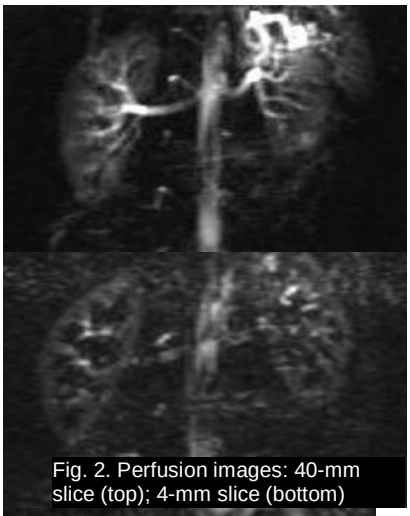

Fig. 2. Perfusion images: 40-mm slice (top); 4-mm slice (bottom)

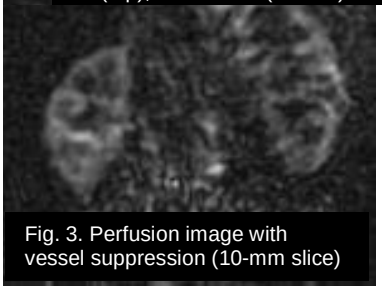

Fig. 3. Perfusion image with vessel suppression (10-mm slice)

**RESULTS:** Figure 2 includes perfusion image-slices taken from 3-D data-sets demonstrating flow in the renal cortex (distinct from the medulla) and spleen, with 40-mm, and 4-mm thick slices. Vessel signal was significantly attenuated by the vessel suppression pulses, as shown in Figure 3. Dynamic perfusion images (40-mm slices) are shown in Figure 4, acquired with labelling times decremented from 3 sec to 0.5 sec, and indicate arrival times to the renal and splenic tissues of 1-1.5 and 1.5-2 sec, respectively, by the onset of the perfusion signal.

**DISCUSSION:** 3-D ASL in the abdomen has great potential for identifying and monitoring the flow to known and new suspicious lesions. 3-D imaging has the advantage of wide coverage with high SNR due to multiple slice-encodes, with only a modest increase in scan time when compared to 2-D imaging that requires multiple signal averages to obtain adequate SNR. Large, 3-D imaging volumes, with dark backgrounds, achievable with the (BGS)-ASL technique demonstrated here will be particularly useful for imaging lesions not only in the kidneys, but in the wider volumes of the liver and abdomen as a whole. The ability to apply vessel suppression with this pCASL technique will be important for separating perfusion and vascular signals. Dynamic perfusion measurements, achieved with pCASL that separates labelling from background signal suppression, may be important for evaluating both tissues and the upstream vasculature. For example, delayed or asymmetric arrival times in the kidneys may indicate the severity of renal artery stenoses. More rapid dynamic imaging, within a single breath-hold, may be achieved by acquisition of single projection images, possible with subtraction, BGS-ASL techniques.

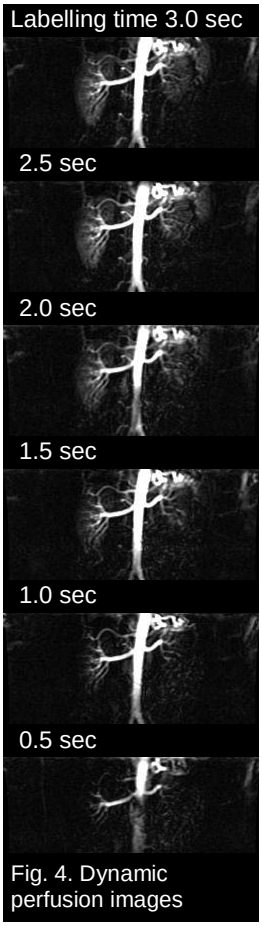


Fig. 4. Dynamic perfusion images

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